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WATER QUALITY RESEARCHES: SPECTRAL VARIABILITY OF THE WATER BODY ANALYSIS TO DEFINE A SAMPLING SCHEME

Pesquisas de Qualidade da Água: Análise da Variabilidade Espectral do Corpo D´Água na definição de um Esquema Amostral

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ABSTRACT

The characteristics variation of the water quality in reservoirs occurs in a complex way and usually the number of points surveyed in limnological researches is not enough to evaluate a significant number of parameters and theirs correlations. In this context, the aim of this work is to define a sampling scheme that considers an adequate number of points for the analysis of the water quality in water reservoirs.In this perspective, techniques of digital image processing were applied, a multitemporal analysis of satellite images in four distinct dates was carried out ad a scheme of sampling based on radiometric variations observed in the water body was defined.The study area is the Capivara Reservoir that belongs to the Paranapanema River Hydrographic Basin in the State of Paraná and São Paulo - Brazil, which is the limit border of the State of Paraná and an important integration axis between these two states. The sampling scheme applied to the area was based on the stratified random method, and stratification was defined for the spectral variability of the water body. The final size of the sampling scheme was 15 points, distributed throughout the course of the reservoir and in the tributaries. The sample points were precisely located by navigation GPS and GNSS. The limnological data was collected "in situ" in each point defined for the sampling scheme using GPS and GNSS receivers in order to guarantee fidelity in the tasks of data measures and collects.

Keywords: Water Quality, Spectral Variability, Sampling Scheme.

RESUMO

As características de qualidade da água em reservatórios ocorrem de modo complexo e interdependente ao longo de sua extensão e, em geral, o número de amostras levantadas em pesquisas limnológicas tradicionais, muitas vezes não é suficiente para uma análise estatística robusta das correlações entre esses parâmetros. Nesse contexto, o objetivo principal dessa pesquisa é definir um esquema amostral que considere um número adequado de pontos para análise da qualidade da água em reservatórios. Nessa perspectiva, técnicas de processamento digital de imagens e análise multitemporal de imagens de satélite tomadas em quatro datas distintas foram realizadas, na confecção de um esquema amostral baseado nas variações radiométricas observadas no corpo d´água. A área de estudo foi o Reservatório da Usina Capivara, pertencente à Bacia Hidrográfica do Rio Paranapanema, que faz fronteira entre os Estados do Paraná e São

Paulo - Brasil, sendo um importante eixo de integração entre esses dois Estados. O esquema amostral aplicado à área de estudo foi baseado no método sistemático não alinhado com posterior estratificação, definida conforme a variabilidade espectral do corpo d´água, realocando-se os pontos. A amostra final gerada apresentou 15 pontos, distribuídos no curso principal do rio e em seus tributários. Os pontos amostrais foram precisamente posicionados com GPS de navegação e GNSS. Os dados limnológicos foram coletados " in situ" para cada ponto definido pelo esquema amostral usando receptores GPS e GNSS, garantindo a fidelidade e posicionamento dos dados medidos e coletados.

Palavras chaves: Qualidade da Água, Variabilidade Espectral, Esquema Amostral.

1. INTRODUCTION

In the last decades of the 20th century issues related to the contamination of water resources and its drought have occupied a prominent role in national and international forums. Experts are drawing an alarming picture for the near future with regard to droughts of drink water on Earth. According to the ANA - Brazilian Water National Agency, until 2015 the drink water will cease to be "Godsend" to become a valuable commodity. We are already experiencing that in Brazil, in 2014!

Tundisi (2003) considers the history of water on Earth complex and directly related to the urban population growth, degree of urbanization and its multiple use, affecting the water quality, quantity and the human health.

In this context, drink water has been the subject of innumerable debates, mainly in the scientific environment, where researches focus on the water availability and quality, preparing diagnoses and solutions for planners and decision makers.

In the nature there are two types of aquatic environments related to the water velocity and flow. These environments are denominated lentic, when there is a hydrological alteration concerning to the river damming, for example, resulting in the formation of a lake; and lotic, when there is a continuous flow such as in streams or rivers. The reservoirs are defined as intermediated environments between rivers and lakes where a continuum of limnological parameters from the river to the dam can be observed (PAGIORO, 1999; JORGENSEN et al., 2000).

The characteristics variation of the water quality in reservoirs occurs in a complex way and usually the number of points surveyed in limnological researches is not enough to evaluate a significant number of parameters and theirs correlations.

Whereas every phenomenon of nature presents a different range of variation depending on the location, the sample size, the number of surveyed points and the sampling scheme must be adequate to the structure of the phenomenon variability (or spatial correlation). This hampers when more than one phenomenon (parameter) is analyzed in the research.

According to Lamparelli et al. (2001) there are several sampling schemes to consider, depending on the region characteristics and the nature of the studied phenomenon.

In this context, the aim of this work is to define a sampling scheme that considers an adequate number of points for the analysis of the water quality in water reservoirs. The collection of limnological "in situ" for each point defined for the sampling scheme using navigation GPS, is also intended.

2. APPROACH AND METHODS

Aiming to develop the research, a medium spatial resolution multispectral image from the Landsat 8 Satellite (dated January 2014 and December 2013) and Landsat 5/TM Satellite (dated June 2001 and May 1987) were obtained. The spectral bands used were bands 2, 3, 4 and 5 from Landsat 8 and bands 1, 2, 3 and 4 from Landsat 5, with intervals of wavelenght between 450 and 520 nm (blue); 520 and 600 nm (green); 630 and 690 nm(red); 760 and 900 nm (near infrared), defined by water spectral reflectance interval.

In order to analyze the remote sensing data, the softwares Spring 5.2.7 (INPE/Brazil) and Idrisi (University of Wisconsin/USA) were used. For the sample elements positioning "in situ" the precision GNSS Promark 500 and the navigation GPS Garmin 12 etrex were used. For the limnological data collection "in situ" a Van Dorn bottle, plastic bottles and a Secchi disk were used.

Te method adopted to sampling scheme

was a temporal analysis of multispectral data from the selected satellite image for the study area, in order to observe the spectral behavior of the reservoir water in two representative periods of its dynamic: the dry and the rainy season (Barbosa, 2005; Pereira, 2008; 2011).

2.1 Procedures performed in office

The four Landsat satellite bands were georeferenced in the Spring software with control points collected through a field survey in the study area using the precision GNSS Promark-500. To isolate the water of the reservoir from the surrounding land use a segmentation of the band 5 from Landsat 8 imagery was done for the rainy season, January 2014 and December 2013. The image from January 2014 that had the greater area of inundation to define the limit of the reservoir boundary was compared and selected.

This representation composed a layer (Information Plans PI) relative to the four temporal images from Landsat 8 and Landsat 5 satellite. An unsupervised classification technique by region growing available in the Spring software was adopted. The Isoseg classifier was used in the region unsupervised classification defined in the segmentation. The threshold value was 95% after several tests.

After the classification technique a class mapping was made using the own numbers generated by the classification, allowing to compare the various classes generated by the Idrisi overlap, through the GIS Analyses Tool. In Idrisi the sampling scheme tests for the best points localization "in situ" were also done.

According to Lamparelli et al. (2001) there are many sampling schemes to be considered, depending on the region characteristics and the nature of the studied phenomenon. They may be: regular or systematic, those sample elements which are made by points equally spaced and homogeneously distributed throughout the considered region; random, those whose points are fixed randomly by region and where there are no problems of bias - in this case the randomization cancels the effect of any existing standards- ; and finally the stratified random or systematic unaligned, those which cover the total area of interest and preserve the causality.

This research sampling scheme was made through sampling techniques generated by the Idrisi software. This tool inserts points in the area, randomly from the choice of method and the number of points.

The sampling techniques tested in this research were the systematic and the stratified random with initial samples with different sizes. These were applied to the reservoir, in this case, to the area of the largest outline of flooding (January 2014).

After the systematization of the points a stratification and integrated analysis with dry and rainy season imagery was done, observing if the points localization was coincident with transitions regions and with higher spectral variation over time. This stratification was based in Thompson (2002) which defines variable sampling schemes according to the cost of the obtaining samples. According to Thompson (2002) the ideal stratification scheme allocates larger sample sizes in larger regions or more variables and smaller sample sizes in more expensive regions or the ones more difficult to be sampled.

In the research areas with greater spectral variation and those classified as temporal transition areas were considered, allocated with larger number of sample elements than areas with less spectral variability over time.

2.2 Procedures performed "in situ"

The procedures performed "in situ" in this research were the geodetic positioning with GNSS and GPS and the limnological data collection - solids and chlorophyll-a.

2.2.1 Geodetic Positioning "in situ"

In each point from the sampling scheme was tracked in field the precision positioning thereof. For this it was used a dual frequency precision Promark 500 GNSS.

The boat used as a transport vehicle in the reservoir for the data collection rode up the Promark 500 GNSS. The positioning method was relative static with 5 minutes time trace for each point. To correct the pre-determined points localization, within the reservoir, Garmin etrex GPS was used.

2.2.2 Limnological data collection "in situ"

For the limnological data collection "in situ" Van Dorn bottles were used, where water was suctioned through a 30 meter length hose marked on the metro subway and released in bottles to water sampling. According to Cavenaghi (2003) this collector increases the stability and its representative results are because it does not allow the turbulence of the sample at the time of the collection.

The Secchi disk was used for measuring the reservoir depth through water transparency. Water was collected in the Secchi disk and stored in plastic bottles, kept in styrofoam ice and forwarded to the UEL chemistry laboratory for analysis of solids and chlorophyll-a.

3. RESULTS

Figures 1, 2, 3 and 4 presents the unsupervised classification generated with four temporal imagery bands researched through the Spring software.

Fig. 2 – Unsupervised Classification of Capivara Reservoir PR/SP, generated by Landsat 8 imagery - December 2013 (rainy season).

Fig. 1 – Unsupervised Classification of Capivara Reservoir PR/SP, generated by Landsat 8 imagery - January 2014 (rainy season).

Fig. 3 – Unsupervised Classification of Capivara Reservoir PR/SP, generated by Landsat 5 imagery - June 2001 (dry season).

Fig. 4 – Unsupervised Classification of Capivara Reservoir PR/SP, generated by Landsat 5 imagery - May 1987 (dry season).

In figures 1 to 4 the homogeneous areas over time appear in pink and are, generally, represented by the main course of the Paranapanema river and the Capivara Reservoir. The transition and heterogeneous areas are presented in brown and gray colors.

The integration of the rainy season classification (January 2014 and December 2013) and the dry season (June 2001 and May 1987) in Idrisi software was done. It was possible to observe that the spectral characteristics of the reservoir regions with more homogeneous water, less homogeneous water and transition regions, for researched over time from 1987 to 2014.

After the realization of the two sampling techniques with different initial numbers, the stratified random was chosen by ensuring the coverage area, that preserved the causality and 50 initial points in the reservoir were defined.

Then, a stratification was applied in these points, changing their initial positions, according to the analysis of the indicated classified imagery from both rainy and dry seasons.

The points were relocated according to the greater number of homogeneous and transition areas and reduced in the heterogeneous area.

In figure 5 the resulting image that overlaps the two images for the *rainy season* to the Capivara Reservoir PR/SP can be observed. It is possible to observe that the main course of the Paranapanema river is very homogeneous in two analysis date (beige color), the main course of the Capivara reservoir is also homogeneous (green color) whilst the transition region and the less homogeneous area is into the dam of the river (purple color) and mainly in the South-west part, the end of the reservoir in function of the tributaries (dark beige and green).

These images were generated with 5 different color classes and it can be said that there was a higher heterogeneity between the two time periods analyzed for the rainy season.

Therefore the points were concentrated in greater number in these regions where changes were resulting from the temporal studies. It was also detected that the lower number of points are regions more homogeneous as, for example, the main course of the reservoir.

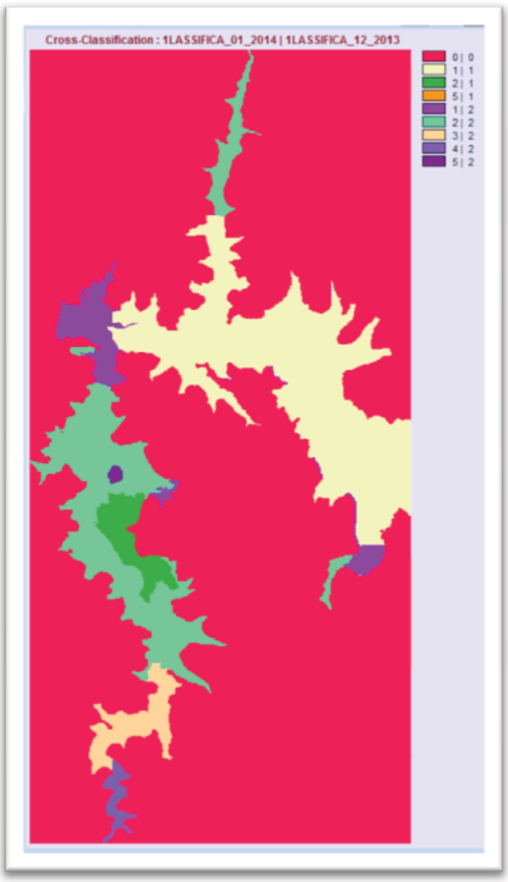

Fig. 5 – Resulting imagery overlaps of the two imagery for the *rainy season* - Capivara Reservoir PR/SP.

It can be observed in figure 6, which represents the resulting overlaps of the two imagery for the *dry season* - the Capivara

Reservoir PR/SP, that the main course of the Capivara reservoir is fully homogeneous (beige color). In this image was generated only 1 class that was a higher homogeneity between the two analyzed periods of time for the dry season.

Thereby the points were concentrated in greater number in regions where there was a greater change during the time period analyzed (figure 5).

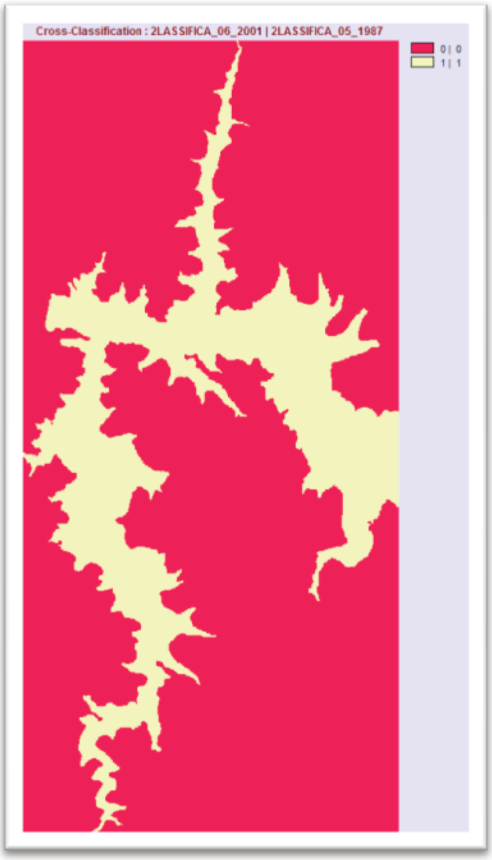

Fig. 6 - Resulting imagery overlaps of the two imagery for the dry season - Capivara Reservoir PR/SP.

In the total 15 sample points were defined (stars in map) in the Capivara PR/SP reservoir, scattered along the reservoir and the tributaries, ensuring a good representation of limnological characteristics collected "in situ". Figure 7 presents the sample scheme map with plan coordinates (UTM) used to represent the points resulting from the navigation in the reservoir.

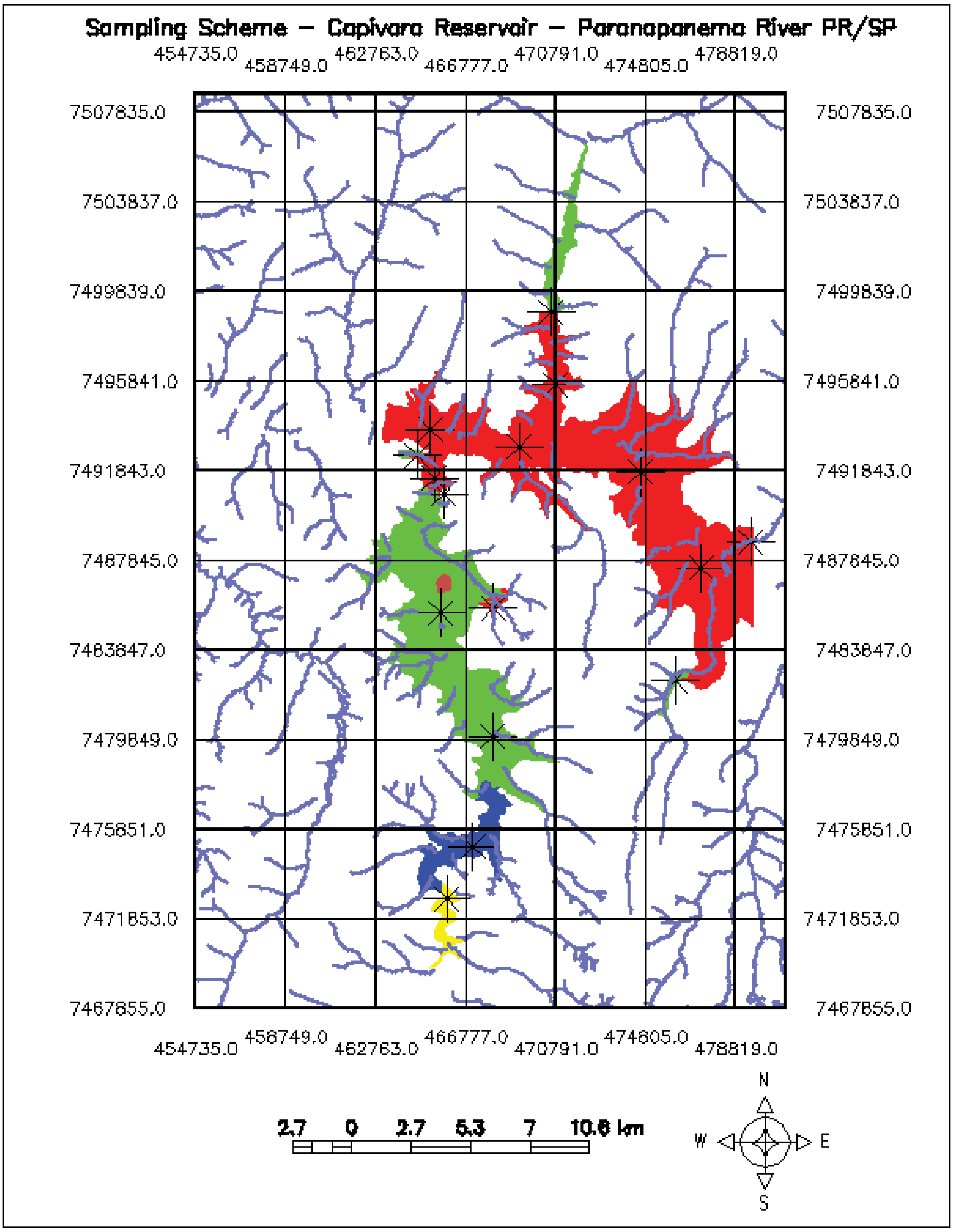

Fig.7 – Capivara Reservoir Sketch with hydrography and 15 points sampling scheme (stars).

4. CONCLUSION

In water quality studies to propose the definition of the size of the sample to increase the sampling scheme question must be carefully evaluated, mainly because of the high cost in collection and water analysis.

Therefore this research proposed a sampling scheme methodology that considers a scheme of sampling based on the observed radiometric variations in the water body using multitemporal and multispectral imagery taken in two periods representing its dynamics: rainy and dry season, in the last 27 years.

Based on the imagery, spectral variability sample elements were distributed in the area with the stratified random method, and the stratification was applied in some of these points, relocating their initial positions according to the classified imagery of the rainy and dry seasons analysis.

The final sample size was 15 points

distributed throughout the reservoir's main course and tributaries.

Nowadays, the data collected "in situ" took place on November 10/2014 and it is in laboratorial analysis to total solids in suspension TSS, Chlorophyll-a, temperature and Secchi disk depth. In each collected point the positioning with precision and navigation GPS was realized.

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